Google | Privacy, Safety & Security

Post-quantum Cryptography at Google

Stefan Kölbl

Symposium PQC, Netherlands

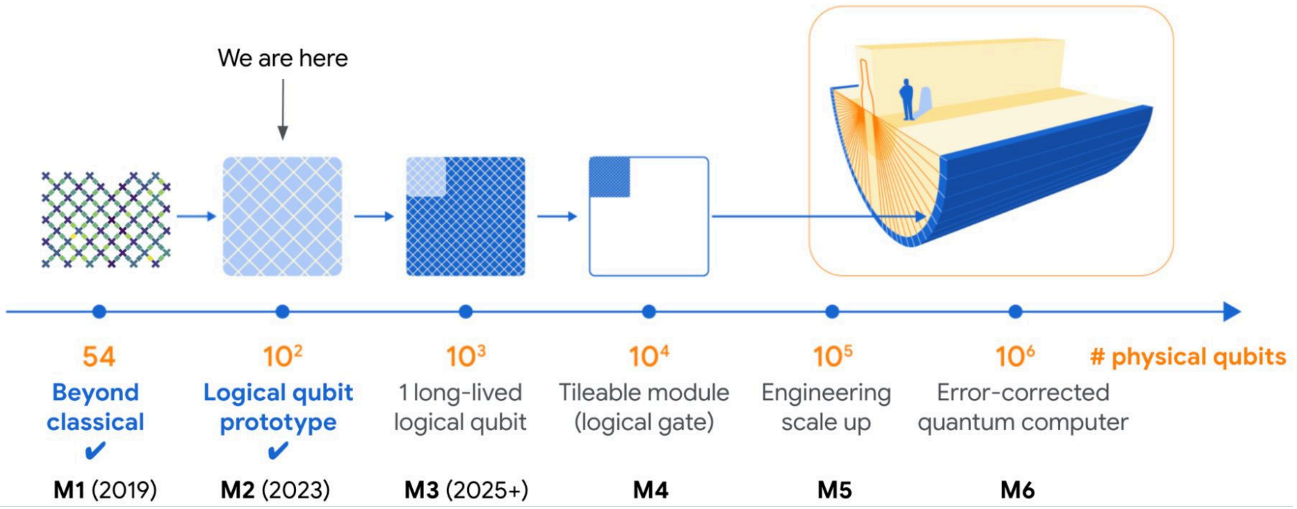
June 13th, 2023

Agenda

1. Our view on post-quantum cryptography
2. Deploying PQC at scale
3. Engineering to ease migration

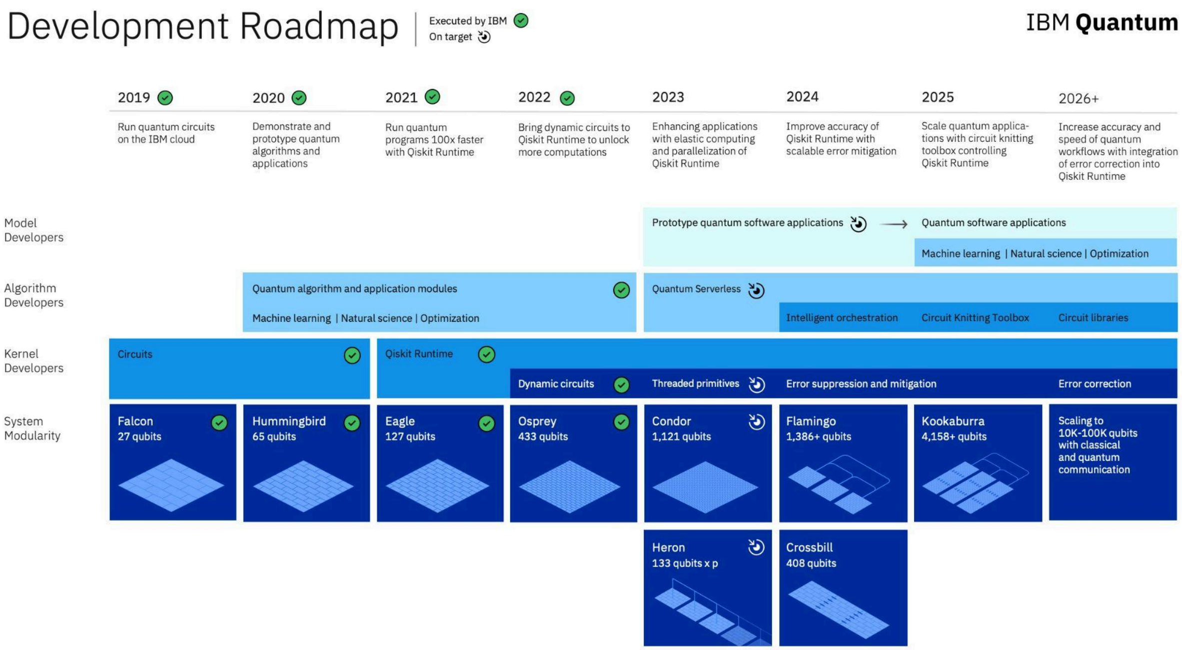
Part I - Where are we today?

When will we get a quantum computer?



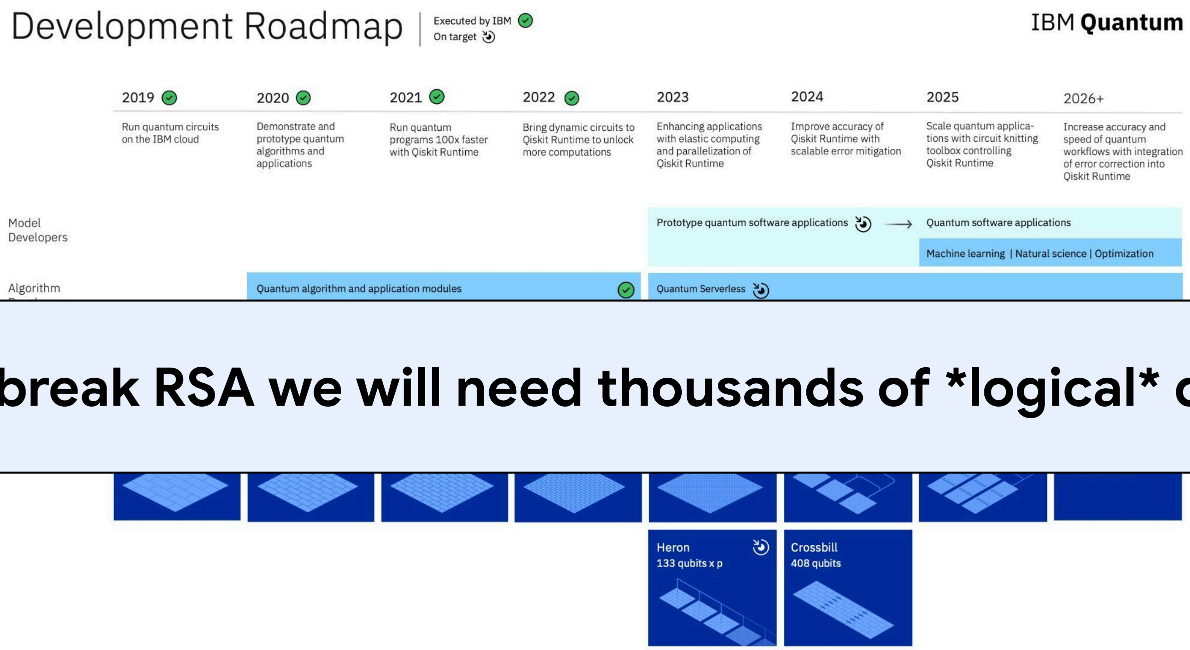
https://ai.googleblog.com/2023/02/suppressing-quantum-errors-by-scaling.html

When will we get a quantum computer?



https://www.ibm.com/quantum/roadmap

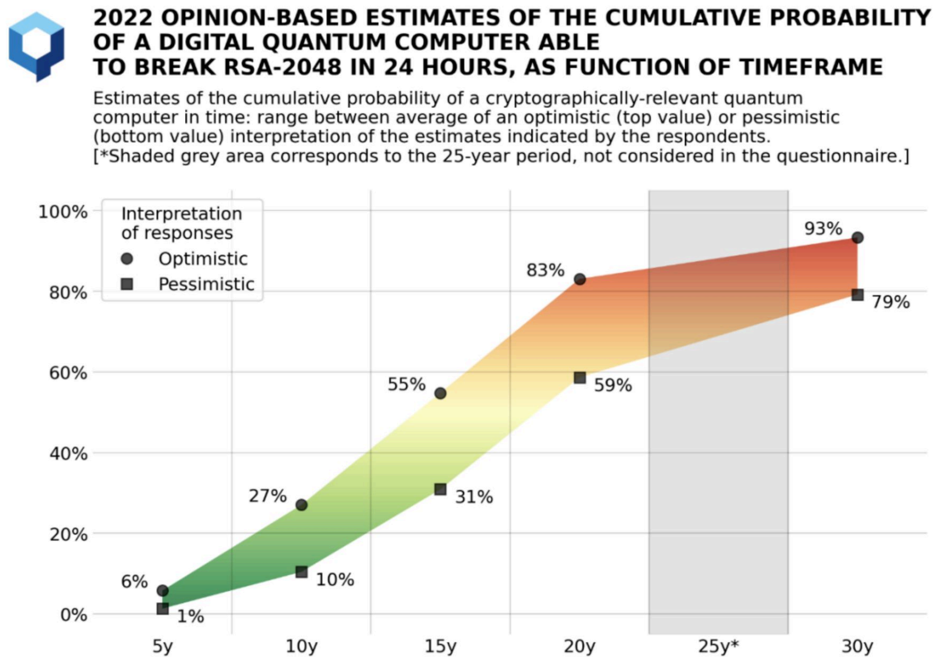
When will we get a quantum computer?



To break RSA we will need thousands of *logical* qubits

https://www.ibm.com/quantum/roadmap

When will we get a quantum computer?



https://globalriskinstitute.org/publication/2022-quantum-threat-timeline-report/

Why care about a threat that does not exist yet?

Why we care about this today

Impact of cryptography failing

Migration takes a long time

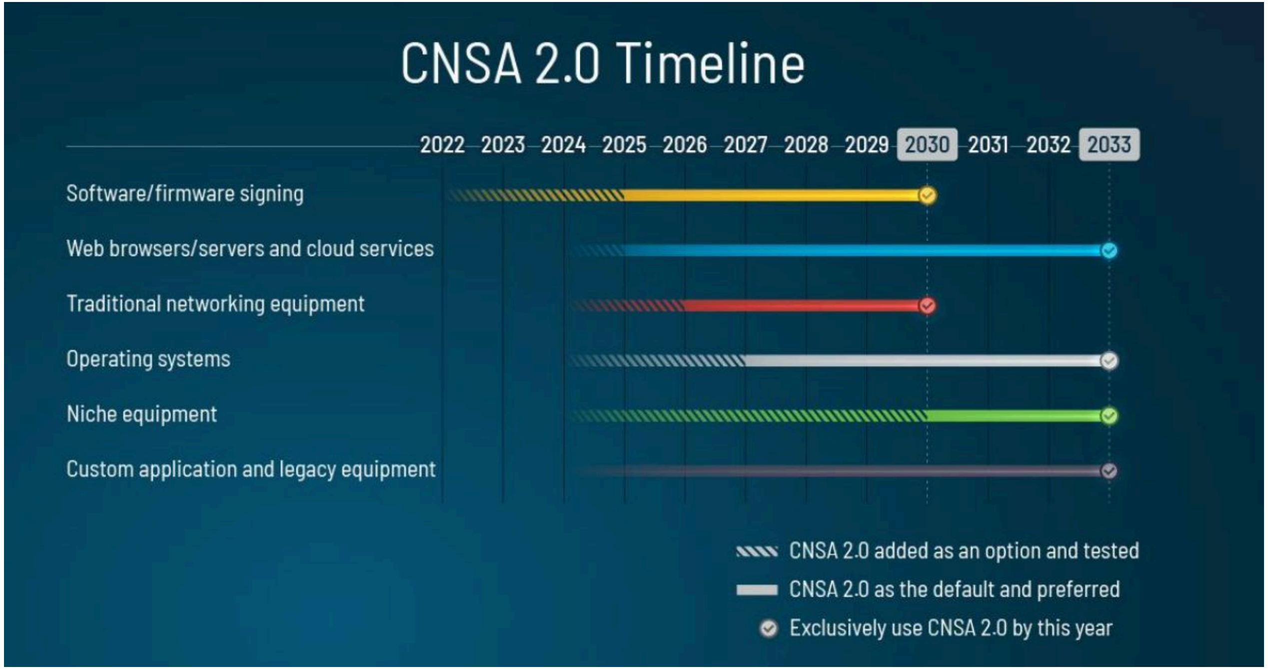
Store now – decrypt later

PQC Standards

Algorithms

- **IETF RFC-8391, RFC-8554, ISO 14888-4 & NIST SP 800-208**
  - Scope: Stateful Hash-Based Signatures
  - Status: Published (ISO in DIS stage)
- **NIST PQC Competition**
  - Scope: KEMs, Signatures
  - Status: Drafts soon, standards ~Mid 2024
- **ISO/IEC**
  - Scope: KEMs
  - Status: Recently started

PQC Standards



PQC Challenges - Hardware

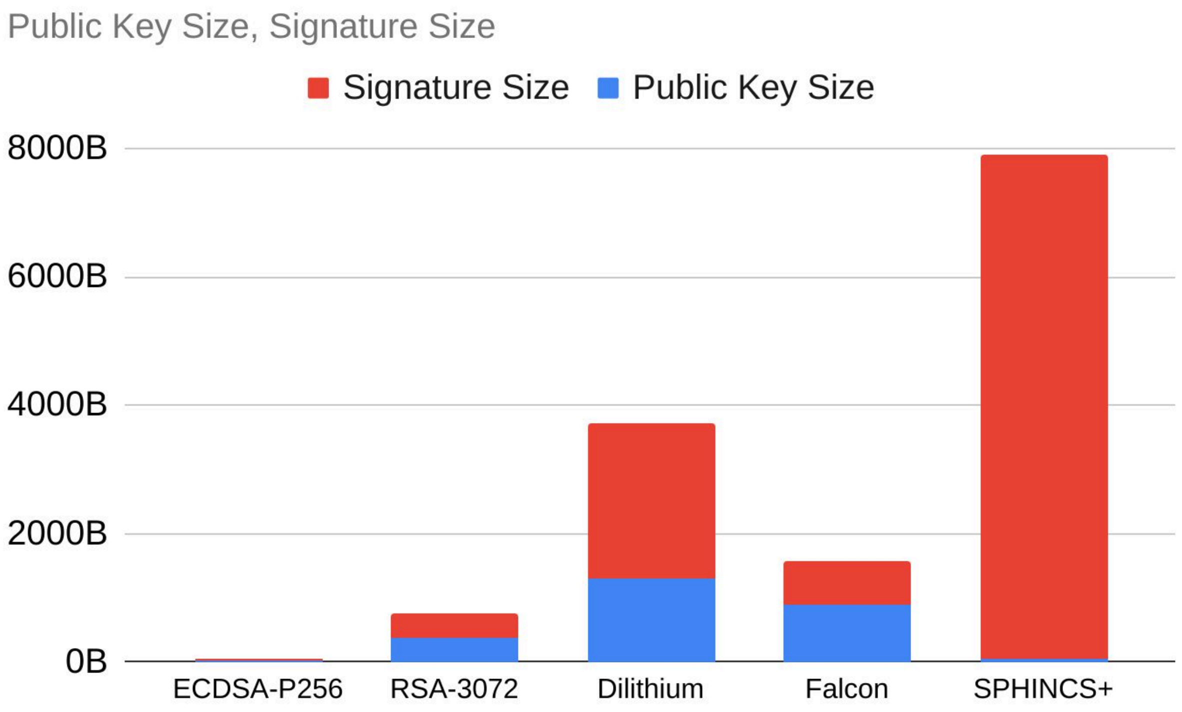
Devices

- Root of trust
- Security keys
- Consumer devices

Challenges

- Long development cycles
- Long devices lifetime
- Difficulty to upgrade
- Resource constrained environments

PQC Challenges - Performance



PQC Challenges - Performance

Challenges with *fancy* crypto:

- Blind Signatures
- (V)OPRF (e.g. Privacy Pass)
  - Communication overhead >100MB*

Huge performance gap between classic <-> PQC

*See https://eprint.iacr.org/2023/232

PQC Challenges - State management

LMS/XMSS (stateful hash-based signatures)

- Only makes sense if SPHINCS+ performance is prohibitive.
- State management complicates signing infrastructure significantly.

Slowly sees adoption:

- Recommended by CNSA 2.0, ANSII (France), BSI (Germany)
- Already used in: OpenSSH, mbedTLS, Infineon TPM

PQC Priorities

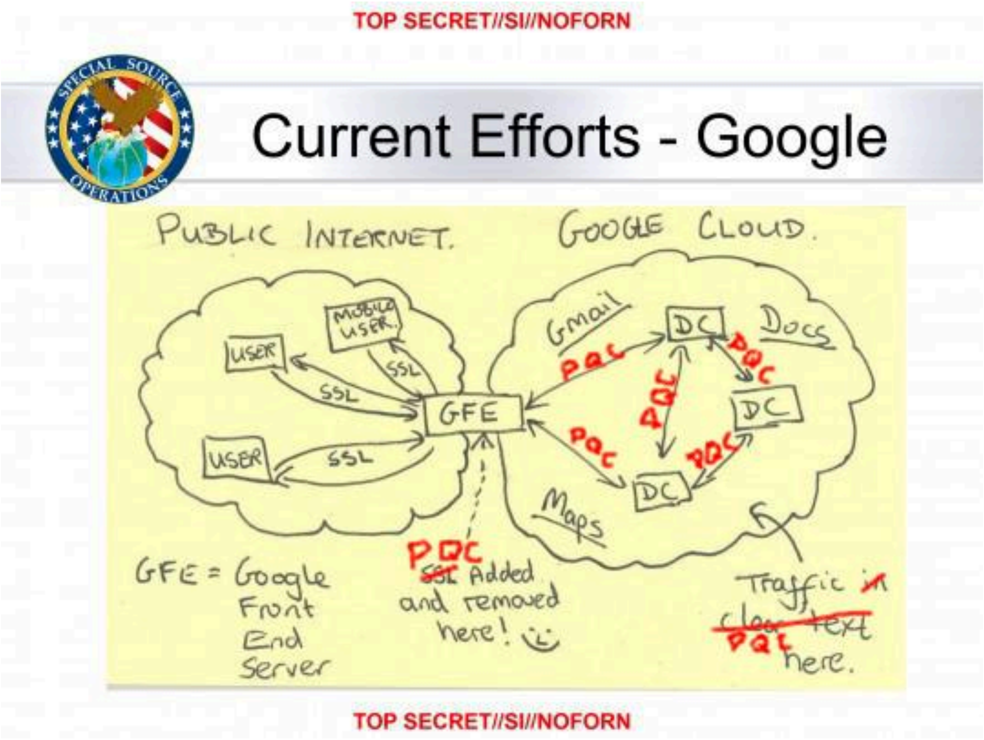
As a large organization, where do you even start?

PQC Priorities

1) Encryption in Transit
2) Signatures, when Public Keys are hard to change
3) All other Asymmetric Cryptography
4) Symmetric Cryptography

Part II - Encryption in Transit

ALTS: Overview



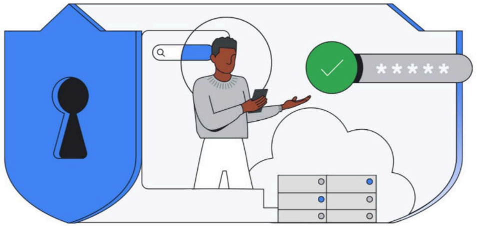
Bringing PQC to ALTS

- ALTS protects all our internal traffic
- Ideal candidate for early PQC adoption
- Enabled a PQC algorithm
  - Deployed in Hybrid mode
  - X25519 + HRSS

Security & Identity

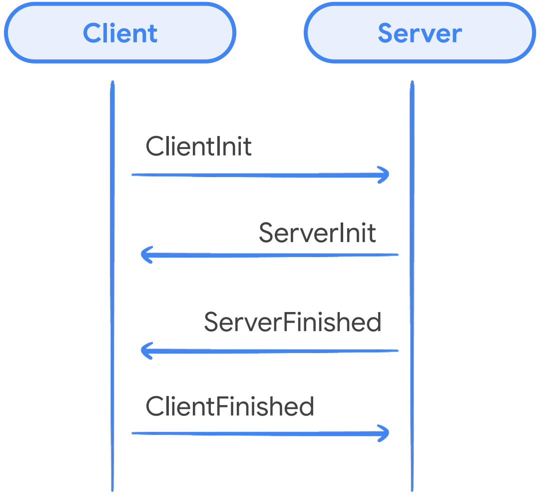
Securing tomorrow today: Why Google now protects its internal communications from quantum threats

November 19, 2022



https://cloud.google.com/blog/products/identity-security/why-google-now-uses-post-quantum-cryptography-for-internal-comms/

ALTS: Overview



ClientInit

- static ECDH key
- cert for ECDH key

ServerInit

- static ECDH key
- cert for ECDH key

ServerFinished

- HMAC(shared_secret, server_const)

ClientFinished

- HMAC(shared_secret, client_const)

Documentation: https://cloud.google.com/docs/security/encryption-in-transit/application-layer-transport-security

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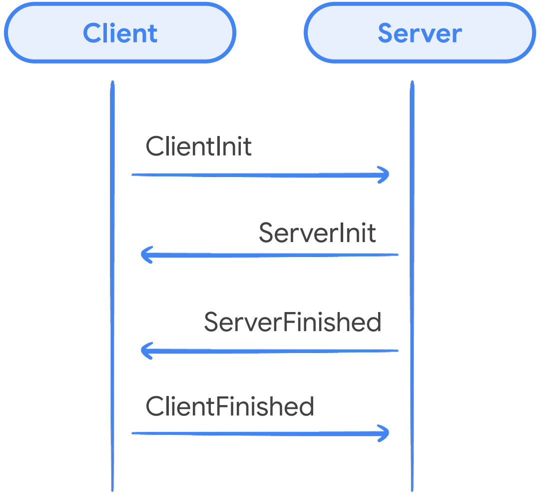

ClientInit

- static ECDH key
- cert for ECDH key
- resumption ticket

ServerInit

- resumption confirmation

ServerFinished

- HMAC(shared_secret, server_const)

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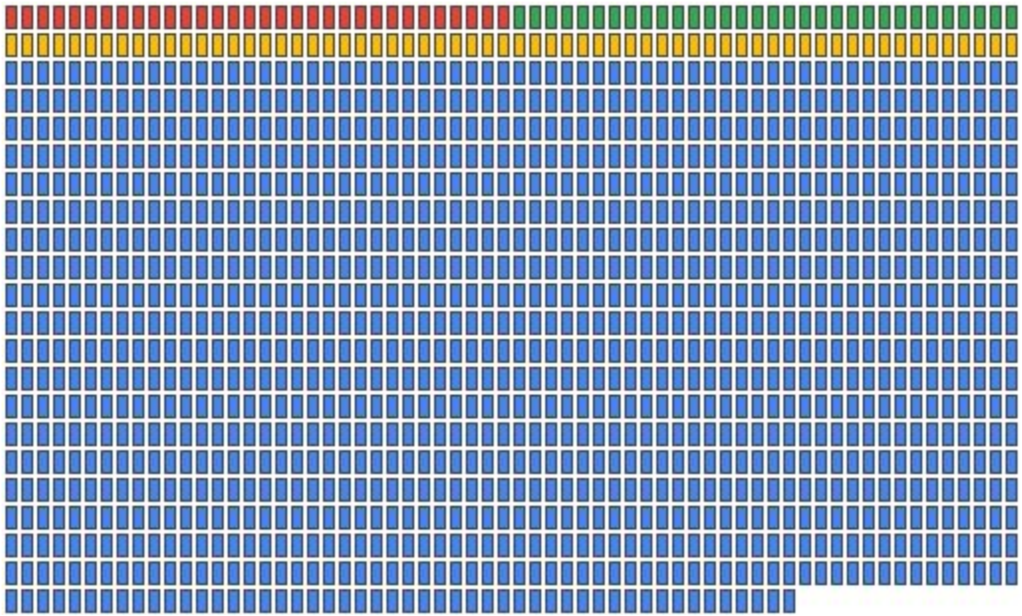
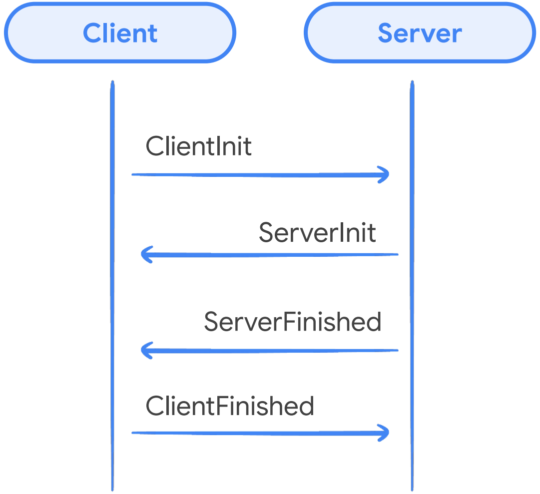
PQC Overview



ALTS PQC



ClientInit

- static ECDH key
- cert for ECDH key
- ephemeral PQC public key

ServerInit

- static ECDH key
- cert for ECDH key
- PQC KEM ciphertext

ServerFinished

- HMAC(shared_secret, server_const)

ClientFinished

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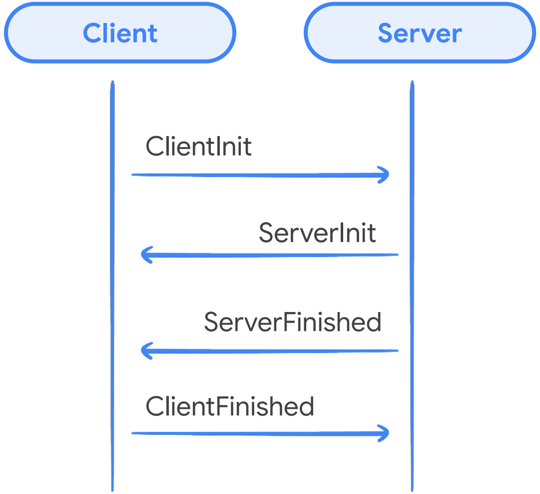
ALTS PQC



ClientInit

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- somewhat ephemeral PQC public key

ServerInit

- static ECDH key
- cert for ECDH key
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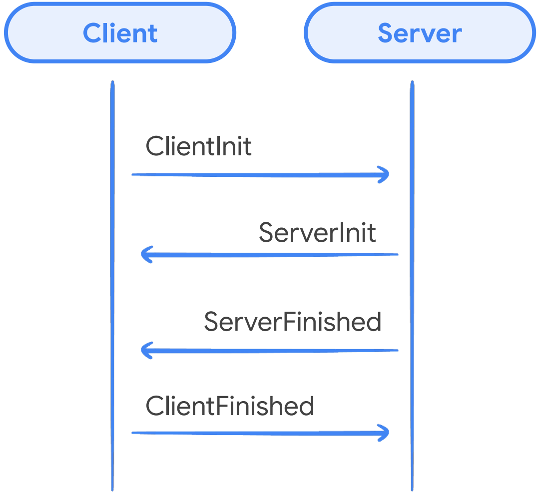
ALTS PQC



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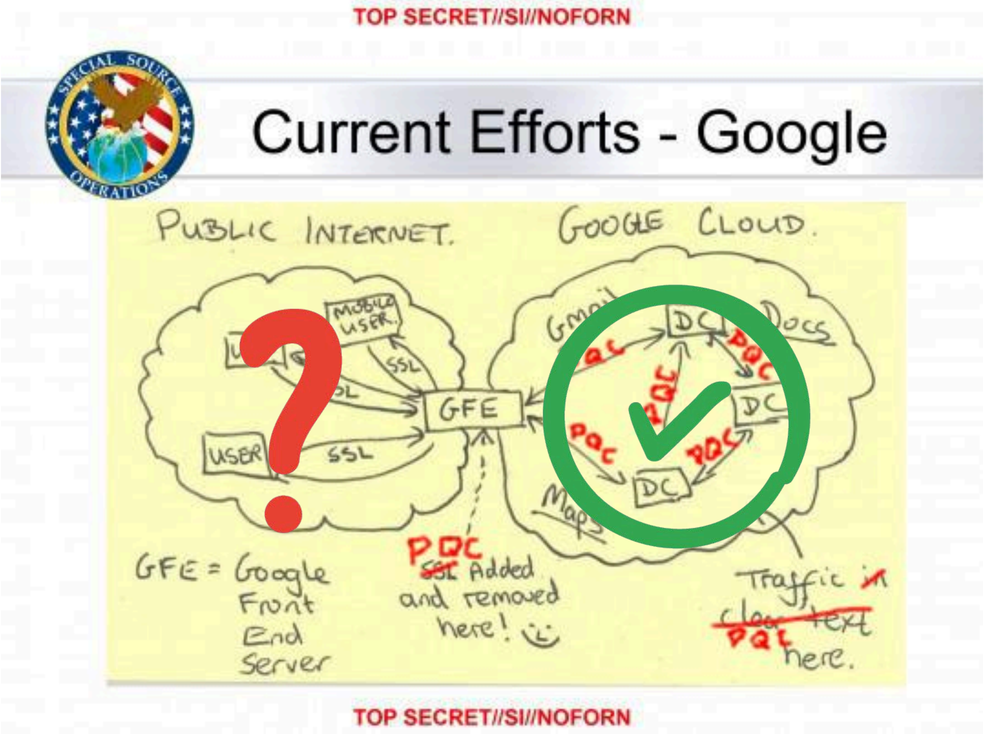
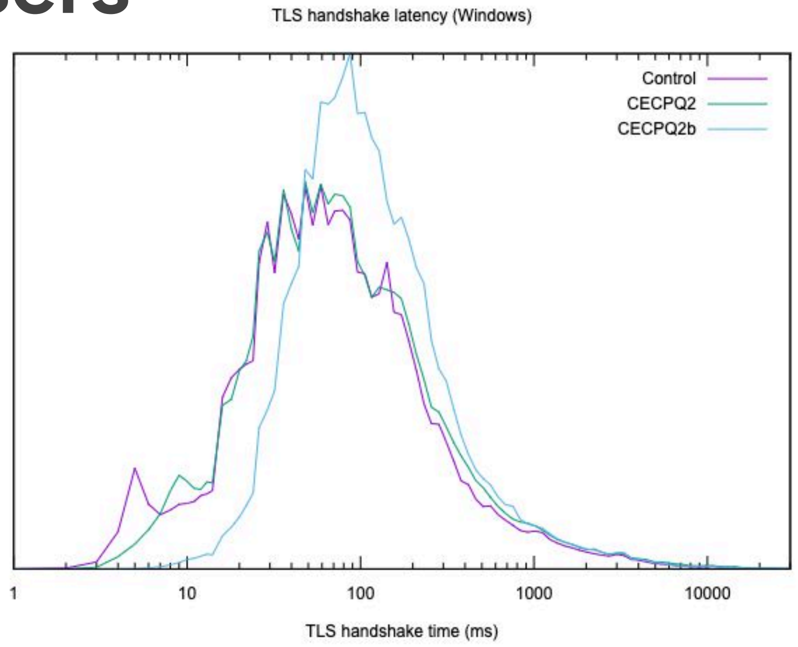
Encryption in transit



Bringing PQC to end-users

- Traffic to user protected by TLS
- Chrome supporting hybrid key-exchange:
  - CECPQ1 (2016)
  - CECPQ2 (2019)

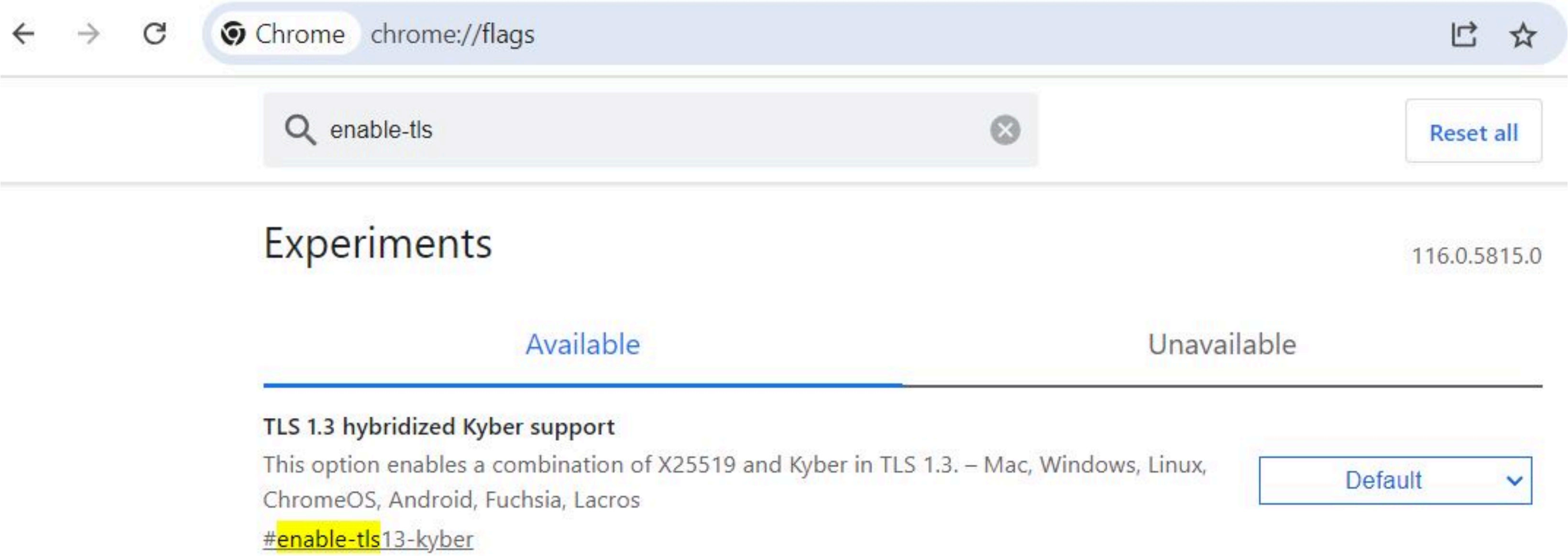


More info at: https://www.imperialviolet.org/2019/10/30/pqsivssl.html and https://blog.cloudflare.com/the-tls-post-quantum-experiment/

Bringing PQC to end-users

- Download Chrome Canary
  - https://www.google.com/chrome/canary/
- Example test site:
  - https://pq.cloudflareresearch.com/

Bringing PQC to end-users



Bringing PQC to end-users


pq.cloudflareresearch.com

Cloudflare Research: Post-Quantum Key Agreement

On essentially all domains served through Cloudflare, including this one, we have enabled hybrid post-quantum key agreement. Read our blog for the details.

You are using *X25519Kyber768Draft00* which is **post-quantum secure**.

Part III - Engineer for agility

Crypto Agility at Google

Our main goal is to make crypto usable for engineers:

- RWC'18: Achieving high availability in the internal Google KMS.
- RWC'19: Tink: A cryptographic library.
- RWC'21: What's in a key?
- RWC'23: Crypto Agility and Post-Quantum Cryptography

Tink

- A multi language and multi-platform open source cryptography library.
- https://github.com/google/tink

Tink

Enforce best practices

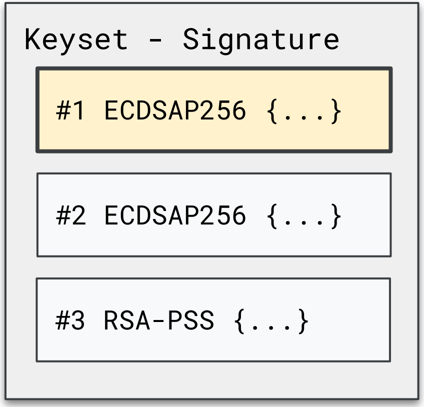
Don’t burden the user

Reliability

Tink - Keysets

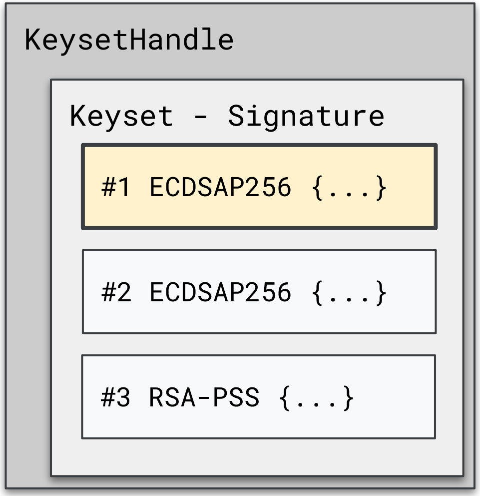
Core concept is that users always use a **keyset**

- A set of keys which implement **the same primitive.**
- Facilitates key rotation.



Tink - Keyset handle

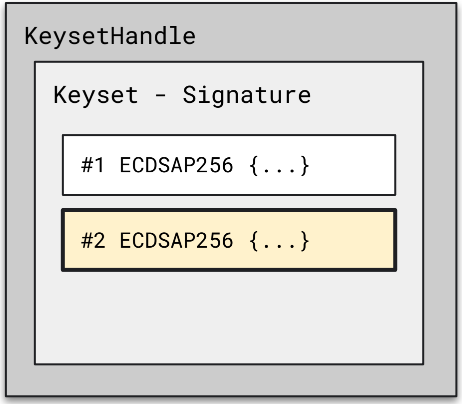
- Restricts access to sensitive data
- Provides API to obtain a primitive wrapping the keyset, e.g. for signatures:
    - `sign(...)`, uses primary key #1
    - `verify(...)`, finds key to verify



Example: Signing data

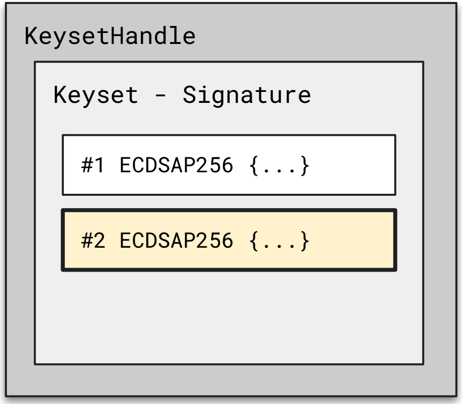
```
import tink
from tink import signature

# Create a keyset with a single key and get a handle to it.
keyset_handle = // Fetch the key from a KMS

# Wrap the keyset into a signing primitive.
sign_primitive = keyset_handle.primitive(signature.PublicKeySign)

# Use the primitive to sign (uses the primary key!).
signature = sign_primitive.sign(“mymessage”)
```

Key Rotation



Key #2 is primary key

Key Rotation

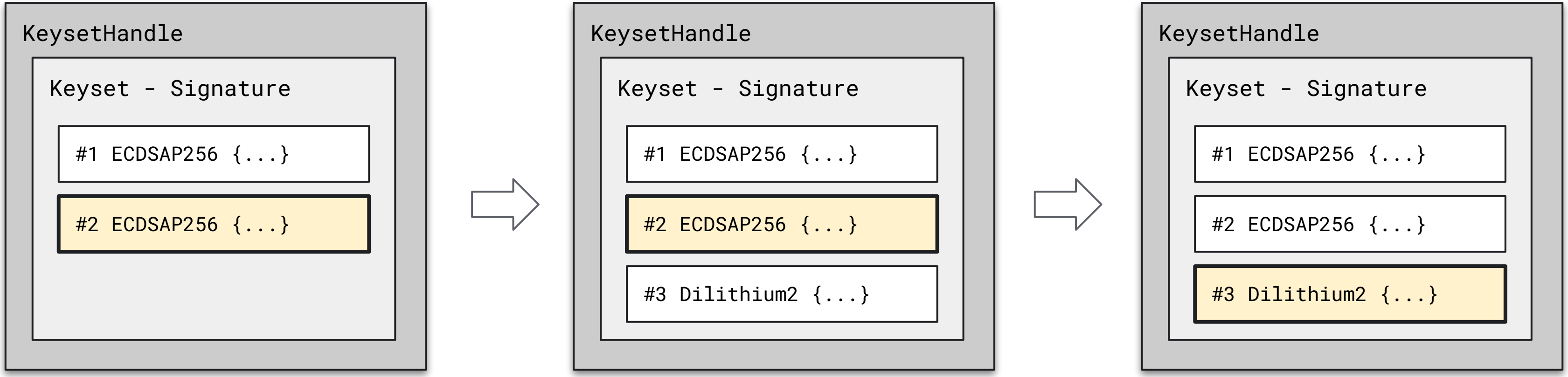


Key #2 is primary key

Tink manages which key is used:

- #2 will sign any new data.
- {#1, #2} will verify signatures.

Key Rotation



Key #2 is primary key

Key #2 is primary key
Key #3 is added

Key #3 is primary key

Key rotation

Key rotation should happen **automatically**

- Forward secrecy.
- Enables speedy recovery from compromise at low operational risk.
- Simplifies switching keys ⇒ Transition to post-quantum crypto.

In practice **hard** to enforce:

- Reliability risks (see RWC'23)

Takeaways

01

Rolling out PQC

We started working on ALTS PQC in 2020, and are now finally getting ready to have rolled out PQC for all jobs, with many unforeseen obstacles along the way.

02

Hybrid deployment

Hybrid deployment allows us to experiment with PQC without risking security regressions. In the worst case, we learned something in an experiment, in the best case we have already mitigated store-now-decrypt later

03

Invest in tooling

Building the right tools for your engineers can ease complex issues around key management, and make migration easier.

Thank you